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2016 Vegetable Fertility Management Trial

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2016 VEGETABLE FERTILITY MANAGEMENT TRIAL

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Many organic vegetable producers have been relying heavily on livestock composts as a source of fertility on farms. Often, high rates of compost are applied to meet the nitrogen (N) needs of crops. When this strategy is implemented, it can lead to over application of phosphorus (P) and potassium (K). As an example, a grower may apply poultry manure at 6 tons ac^{-1} per year to supply vegetable crops with adequate N. This can contribute as much as 180 lbs ac^{-1} of P per year, where vegetable crop removal of P ranges from 10-80 lbs ac^{-1} per season. In this scenario, there is an over application of P, leading to an excess of 100 lbs ac^{-1} of P or more each year the poultry manure is applied. This type of application rate can cause rapid build-up of P in soil and subsequently increase the potential risk of P loss to nearby surface water. Phosphorus loading and associated risk of loss depends on many factors including soil type, slope, and proximity to water. However, with impending water quality regulations, farmers will be required to account for their nutrient balance and work towards minimizing potential nutrient losses into the environment.

There are few alternative fertilizer options for organic growers that primarily provide N with limited P and K concentrations. Sodium nitrate (SN), also known as Chilean nitrate, is a high N fertilizer (16-0-0) that is mined from natural deposits of caliche ore found in the Atacama Desert of northern Chile. Organic growers have been attracted to SN because its N is 100% plant available, even in cold, early season soils, which makes SN especially desirable in regions like New England. There are few alternative, organic options that can quickly provide N to plants.

The goal of this research project was to evaluate the advantages of using SN and blood meal (BM;12-0-0), another organic-approved N fertilizer alternative, in cool, early season conditions to help supply the N requirements of crops and reduce P loading from other types of organic approved fertility sources. The two crops studied were sweet corn and cabbage. These crops were chosen because they are generally planted early in the season, in cold soils, and are relatively heavy N feeders.

MATERIALS AND METHODS

The trial was conducted at Borderview Research Farm in Alburgh, VT. For both crops, the experimental design was a randomized complete block with four replications. The previous crop was sod composed of perennial cool season grasses. The sod was plowed in the fall of 2015. The field was spring disked and rototilled lightly just prior to planting. General plot management is listed in Table 1 and soil test results for the trial area is listed in Table 2.

Table 1. General plot management for both cabbage and sweet corn, 2016.

Trial Information	Borderview Research Farm Alburgh, VT
Soil Type	Benson rocky silt loam 8-15% slope
Previous crop	Sod
Tillage methods	Fall plow and spring disk and rototiller

Table 2. Soil quality characteristics, vegetable fertility trial, Alburgh, VT, 2016.

pH	Organic matter	Phosphorus	Potassium	Calcium	Magnesium	Sodium	Aluminum
	%	ppm	ppm	ppm	ppm	ppm	ppm
6.6	3.33	3.65	50	2240	102	8.0	22.0

The cabbage variety, 'Farao,' was transplanted on 7-May. The sweet corn variety, 'Luscious,' was seeded on 25-May. Plots were 5' x 10' for the cabbage and 10' x 20' for the sweet corn. Cabbage was spaced 30" between rows and 12" within the row. General plot management for each crop is listed in Tables 3 and 4.

Table 3. Cabbage plot information, 2016.

Cabbage Information	Borderview Research Farm Alburgh, VT
Variety	Farao
Nutrient requirements	120 lbs ac^{-1} nitrogen
Planting dates	7-May
Fertilizer dates	5-May poultry manure
	7-May starter fertilizer
	3-Jun topdress
Cupping date	12-Jun
Harvest date	12-Jul
Plant spacing	30" x 12"

Table 4. Sweet corn plot information, 2016.

Sweet Corn Information	Borderview Research Farm Alburgh, VT
Variety	Luscious
Nutrient requirements	115 lbs ac^{-1} nitrogen
Planting dates	25-May
Fertilizer dates	20-May poultry manure
	9-Jun starter fertilizer
	23-Jun topdress
Tasseling date	22-Jul
Silking date	2-Aug
Harvest date	8-Aug
Plant spacing	22,000 seeds ac^{-1}

Main plots were six fertilizer treatments and one unfertilized control (Tables 5 and 6). Fertilizer treatments were determined to meet crop N needs, which is 120 lbs ac^{-1} for cabbage and 115 lbs ac^{-1} for sweet corn based off of the New England Vegetable Management Guide (Univ. of CT, Univ. of Mass, Univ. of ME, Univ. of NH, Univ. of RI, UVM). Fertilizer treatments consisted of poultry manure and BM or poultry manure, BM, and SN, at varying rates and application times.

Poultry manure was applied to all cabbage plots, except the control plots, at a rate of 750 lbs ac^{-1}, on 5-May. Poultry manure was applied to all sweet corn plots, except the control plots, at a rate of 500 lbs ac^{-1}, on 20-May. Poultry manure was only applied to a maximum not to exceed P removal rate of each crop. The goal was to apply at rates that would minimize P build-up in the soil.

Image 1. Sweet corn near side-dressing, Alburgh, VT, 2016.

The remainder of the crop's N needs was met by applying SN and BM at two different times (starter and topdress). The SN and BM applied as starter were incorporated around the base of each plant during cabbage transplant (7-May) and at the V1 stage for sweet corn on (9-Jun). The SN and BM applied as a topdress was incorporated around the base of each plant on 3-Jun for the cabbage, at the cupping stage (initiation of head formation), and 23-Jun for the sweet corn, when plants were 6-12" tall (Image 1).

Table 5. Cabbage fertilizer treatments, Alburgh, Vermont, 2016.

Treatment	Blood meal (12-0-0)			Sodium nitrate (16-0-0)		
	lbs ac^{-1}	% N need	Timing	lbs ac^{-1}	% N need	Timing
S – BM high	687	69	S	0	0	---
S – BM med and SN low	487	49	S	150	20	S
S – BM low and SN high	287	29	S	300	40	S
T – BM high	687	69	T	0	0	---
S – BM med, T – SN low	487	49	S	150	20	T
S – BM low, T – SN high	287	29	S	300	40	T
CONTROL	0			0		

S = starter, applied on 7-May; T = topdress, applied on 3-Jun
BM = blood meal; SN = sodium nitrate

Table 6. Sweet corn fertilizer treatments, Alburgh, Vermont, 2016.

Treatment	Blood meal (12-0-0)			Sodium nitrate (16-0-0)		
	lbs ac^{-1}	% N need	Timing	lbs ac^{-1}	% N need	Timing
S – BM high	750	78	S	0	0	---
S – BM med and SN low	558	58	S	144	20	S
S – BM low and SN high	367	38	S	288	40	S
T – BM high	750	78	T	0	0	---
S – BM med, T – SN low	558	58	S	144	20	T
S – BM low, T – SN high	367	38	S	288	40	T
CONTROL	0			0		

S = starter, applied on 9-Jun; T = topdress, applied on 23-Jun
BM = blood meal; SN = sodium nitrate

For both crops, soil nitrate samples were taken every two weeks until harvest. Soil temperature was continuously measured after seeding and transplanting using small, temperature recording devices called Thermochron I-buttons, made by Embedded Data Systems (Lawrenceburg, Kentucky). The I-buttons were buried 4 inches beneath the soil surface. Soil moisture was measured weekly using a soil moisture thetaprobe, made by Delta-T Devices (Cambridge, UK).

The middle four heads of cabbage per plot were harvested by hand on 12-Jul. At harvest, the following quality standards were measured: uniformity was measured visually over the entire plot to estimate whether all the heads were maturing at the same time and whether there were abnormalities, using a 1 (low uniformity) to 9 (high uniformity) scale; head solidity was measured visually and by touch over the four middle heads, using a 1 (less solid) to 9 (more solid) scale; weight of each head harvested was measured; leaf thickness of the outer, wrapper leaf was measured for each harvested head using a digital caliper; tipburn was measured by cutting each head longitudinally and examining the young, inner leaves for necrotic margins and noted as either present or absent; and percent moisture was measured by sampling approximately 1 cup of each of the four heads harvested, chopping the cabbage in a food processor, and then taking approximately ½ cup of the chopped cabbage and recording the wet weight and drying it at 105° F till it reached a stable dry weight.

The corn tasseling date was 22-Jul and the silking date was 2-Aug for sweet corn in all treatments (Table 5). Just prior to harvest, populations were counted and plant height and ear height were measured from the middle two rows only. Sweet corn was harvested by hand on 8-Aug from the middle two rows. At harvest, stalk nitrate was measured by taking 8” stalk samples 6” above the ground level. Samples were sent to Dairy One Laboratory (Ithaca, NY) for analysis. Percent moisture was measured by shaving kernels off of 3 ears per plot, making a slurry of the kernels in a food processor, and then taking approximately ¼ cup of the slurry and recording the wet weight and drying it at 105⁰ F till it reached a stable dry weight. The number of ears in the middle two rows of corn was recorded. Also, the ear length, ear diameter, length of unfilled tip, husked corn ear weight, and unhusked corn ear weight were measured for 10 randomly selected ears from the middle two rows of corn per plot. Uniformity was measured visually over the entire plot and for a subsample of 10 randomly selected husked corn ears and rated on a 1 to 9 scale (low-high). Northern corn leaf blight and rust were measured visually over the middle two rows of corn and rated on a 0 to 5 scale (no disease – severe infection).

Results were analyzed with an analysis of variance in SAS (Cary, NC). The Least Significant Difference (LSD) procedure was used to separate cultivar means when the F-test was significant ($p < 0.10$).
Variations in yield and quality can occur because of variations in genetics, soil, weather and other growing conditions. Statistical analysis makes it possible to determine whether a difference among varieties is real, or whether it might have occurred due to other variations in the field. At the bottom of each table, a LSD value is presented for each variable (i.e. yield). Least Significant differences (LSD’s) at the 10% level of probability are shown. Where the difference between two treatments within a column is equal to or greater than the LSD value at the bottom of the column, you can be sure in 9 out of 10 chances that there is a real difference between the two varieties. Treatments that were not significantly lower in performance than the highest value in a particular column are indicated with an asterisk. In the example below, A is significantly different from C but not from B. The difference between A and B is equal to 1.5, which is less than the LSD value of 2.0. This means that these varieties did not differ in yield. The difference between A and C is equal to 3.0, which is greater than the LSD value of 2.0. This means that the yields of these varieties were significantly different from one another. The asterisk indicates that B was not significantly lower than the top yielding variety.

Variety	Yield
A	6.0
B	7.5*
C	9.0*
LSD	**2.0**

RESULTS

Seasonal precipitation and temperature were recorded with a Davis Instrument Vantage Pro2 weather station, equipped with a WeatherLink data logger at Borderview Farm in Alburgh, VT. The growing season was dryer than normal with May-Sep getting 7.27 fewer inches of precipitation as compared to historical averages (Table 7). Temperatures in Jun-Jul were comparable to normal averages, while May and Aug-Sep were at least 1.8 degrees warmer than normal, per month. Overall, there were an accumulated 2562 Growing Degree Days (GDDs) this season, approximately 268 more than the historical average.

Table 7. Seasonal weather data collected in Alburgh, VT, 2016.

Alburgh, VT	**May**	**June**	**July**	**August**	**September**
Average temperature (°F)	58.1	65.8	70.7	71.6	63.4
Departure from normal	1.80	0.00	0.10	2.90	2.90
Precipitation (inches)	1.50	2.80	1.80	3.00	2.50
Departure from normal	-1.92	-0.88	-2.37	-0.93	-1.17
Growing Degree Days (base 50°F)	340	481	640	663	438
Departure from normal	74	7	1	82	104

Based on weather data from a Davis Instruments Vantage Pro2 with WeatherLink data logger. Alburgh precipitation data from August-October was provided by the NOAA data for Highgate, VT. Historical averages are for 30 years of NOAA data (1981-2010) from Burlington, VT.

Cabbage fertility trial, Alburgh, VT, 2016

All treatments that received supplemental fertilizer yielded significantly higher than the control (Table 8). Treatments with SN and BM applied as supplemental fertilizer yielded significantly higher than the BM only treatments. These results indicate that application of SN provided a yield advantage, which is likely due to the fact that it is plant available even in cold soils. No supplemental fertilizer resulted in the lowest yields, as shown by the control treatment. It is likely that the control plots did not receive enough N early in the season, during the crucial period of plant growth, because the decomposing organic matter from the plow-down sod had not yet become plant available. Mineralization begins once soil temperatures begin to rise over 55°F. The cool soils in the cabbage plots meant low microbial activity and low organic matter mineralization. This indicates the value to adding some readily available N to early season crops that are often grown in cool soils.

Table 8. Cabbage harvest yield data, Alburgh, VT, 2016.

Treatment	Average head weight		Yield	
	lbs	Rank	wet tons ac^{-1}	Rank
S – BM high	2.30	DC	16.0	DC
S – BM med and SN low	2.68*	AB	19.1*	AB
S – BM low and SN high	2.85*	A	**19.9***	**AB**
T – BM high	2.08	D	14.5	D
S – BM med, T – SN low	2.48	BC	17.3	BC
S – BM low, T – SN high	**2.86***	**A**	**19.9***	**A**
CONTROL	1.33	E	9.26	E
p-value	<0.0001		<0.0001	
LSD (0.10)	0.360		2.59	
Trial mean	2.37		16.6	

*Treatments marked with an asterisk did not perform statistically worse than the top performing treatment (p=0.10).
Treatments in **bold** were top performers for the given variable.
Treatments with the same letter did not perform statistically different from one another.
NS – There was no statistical difference between treatments in a particular column (p=0.10).
S = starter, applied on 7-May, T = topdress, applied on 3-Jun.
BM = blood meal; SN= sodium nitrate.

Cabbage quality was also significantly impacted by supplemental fertilizer additions (Table 9). Again treatments with a combination of SN and BM were among top performers for cabbage uniformity and cabbage head solidity (Table 9).

Table 9. Cabbage harvest quality data, Alburgh, VT, 2016.

Treatment	Uniformity		Tipburn	Solidity		Moisture	Leaf thickness
	1= low, 9= high	Rank	1= present, 0= absent	1= less dense, 9= more dense	Rank	%	micrometer
S – BM high	5.00*	AB	0	4.75	C	91.7	1.31
S – BM med and SN low	4.75*	AB	0	**6.00***	**A**	92.3	1.01
S – BM low and SN high	6.00*	AB	0	5.00	BC	92.4	1.16
T – BM high	4.25	B	0	5.00	BC	92.3	1.12
S – BM med, T – SN low	5.00*	AB	0	5.75*	AB	91.7	1.12
S – BM low, T – SN high	**6.25***	**A**	0	6.00*	A	92.4	1.13
CONTROL	2.25	C	0	2.25	D	91.8	0.981
p-value	0.04		N/A	<0.0001		0.50	0.73
LSD (0.10)	1.91		NS	0.890		NS	NS

Trial mean	4.79	0	4.96	92.1	1.12

*Treatments marked with an asterisk were not statistically different than the top performing treatment shown in **bold** (p=0.10).
Treatments with the same letter did not perform statistically different from one another.
NS – There was no statistical difference between treatments in a particular column (p=0.10).
S = starter, applied on 7-May; T = topdress, applied on 3-Jun.
BM = blood meal; SN= sodium nitrate.

The cost of fertilizing using the treatments from this trial is provided below (Table 10). Farmers commonly spend around \$500 ac^{-1} in fertility. However, the return on investing in the fertility treatment may be worth the added yield gain (Table 11). The 'S – BM med and SN low' treatment yielded among the top performers, uses the allowable amount of SN for organic growers (20% of crop N requirements), and has an \$18.87 yield gain for every dollar invested in the fertility treatment. The value of this yield gain is \$16,168 ac^{-1}. The other high yielding treatments, 'S – BM low and SN high' and 'S – BM low, T – SN high' provided higher returns on investment, however, they can only be used by conventional farmers since they exceed the 20% maximum amount of SN allowable for organic farmers.

In addition, it is important for growers to consider the potential gain from reducing the amount of land needed to be cultivated, labor costs, and increased income from higher yield, when deciding on their fertility investment.

Table 10. Cost of cabbage fertilizer treatments, Alburgh, Vermont, 2016.

Treatment	Poultry manure 5-4-3, \$0.25 lb^{-1}		Blood meal 12-0-0, \$1.21 lb^{-1}		Sodium nitrate 16-0-0, \$0.53 lb^{-1}		Total cost
	lbs ac^{-1}	Cost \$ ac^{-1}	lbs ac^{-1}	Cost \$ ac^{-1}	lbs ac^{-1}	Cost \$ ac^{-1}	\$ ac^{-1}
S – BM high	750	188	687	831	0	0	1019
S – BM med and SN low	750	188	487	589	150	80	857
S – BM low and SN high	750	188	287	347	300	160	695
T – BM high	750	188	687	831	0	0	1019
S – BM med, T – SN low	750	188	487	589	150	80	857
S – BM low, T – SN high	750	188	287	347	300	160	695
CONTROL	CONTROL – PREVIOUS YEAR'S SOD CONTRIBUTIONS						

S = starter, applied on 7-May; T = topdress, applied on 3-Jun.
BM = blood meal; SN= sodium nitrate.

Table 11. Yield return per dollar invested in fertility treatment, compared to control treatment, Alburgh, Vermont, 2016.

Treatment	Yield increase over control with no fertilizer	Value of yield increase*	Return per dollar spent in fertilizer	
	wet tons ac^{-1}	\$ ac^{-1}	\$	%
S – BM high	6.74	11188	10.97	1097
S – BM med and SN low	9.74	16168	18.87	1887
S – BM low and SN high	10.64	17662	25.41	2541
T – BM high	5.24	8698	8.54	854
S – BM med, T – SN low	8.04	13346	15.57	1557
S – BM low, T – SN high	10.64	17662	25.41	2541

S = starter, applied on 7-May; T = topdress, applied on 3-Jun.
BM = blood meal; SN= sodium nitrate.
* Using \$0.83/lb cabbage. USDA Economic Research Service, Organic prices, 2012

For both crops, soil nitrate samples were taken every two weeks until harvest. Soil nitrate-N levels were comparable among all treatments for all sample dates, except for the 21-Jun and 5-Jul sample dates (Figure 1). On the 21-Jun sample date, four out of the five fertilizer treatments with BM applied as a starter (7-May) fertilizer peaked in soil nitrate-N levels, about 45 days after the BM was applied. Of the three treatments that did not peak in soil nitrate on 21-Jun, one was the control which did not receive BM and another received BM later in the season, as a topdress application. Essentially, the BM requires roughly 45 days for the majority of the nitrogen to become plant available and was likely too late to meet the majority of the N requirements of the cabbage crop.

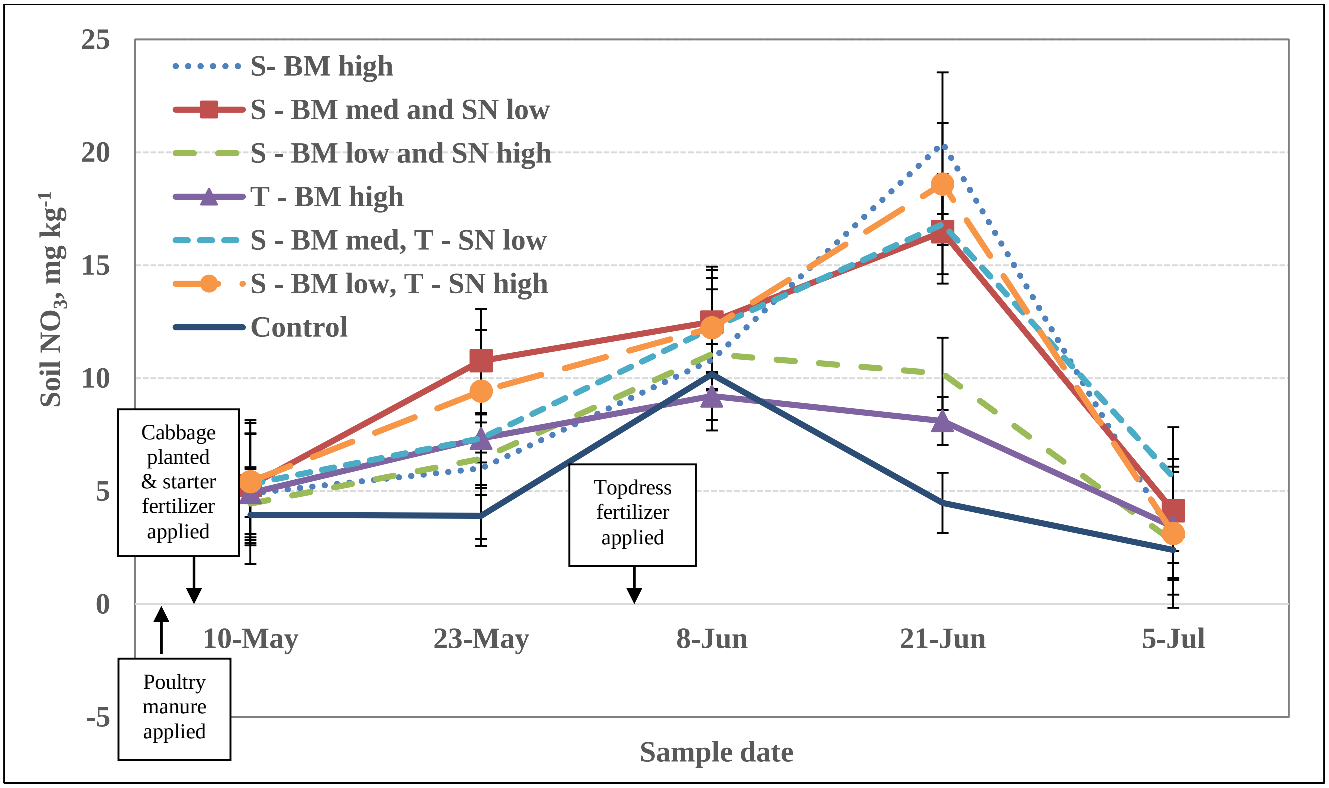

Figure 1. Soil nitrate levels in the cabbage fertility trial, 10-May and 23-May p-value = 0.48, 8-Jun p-value = 0.17, 21-Jun p-value = 0.01, 5-Jul p-value = 0.001, Alburgh, VT, 2016.

As to be expected with a spring cabbage planting, soil minimum temperatures were relatively cool in May (Figure 2). Soil moisture was relatively low and the season was fairly dry. Interestingly, soil moisture experienced a peak on 8-Jun, which coincides with when the soil nitrate levels peaked in the control plots (Figure 1). It is possible that the increased moisture aided with sod decomposition and therefore N availability.

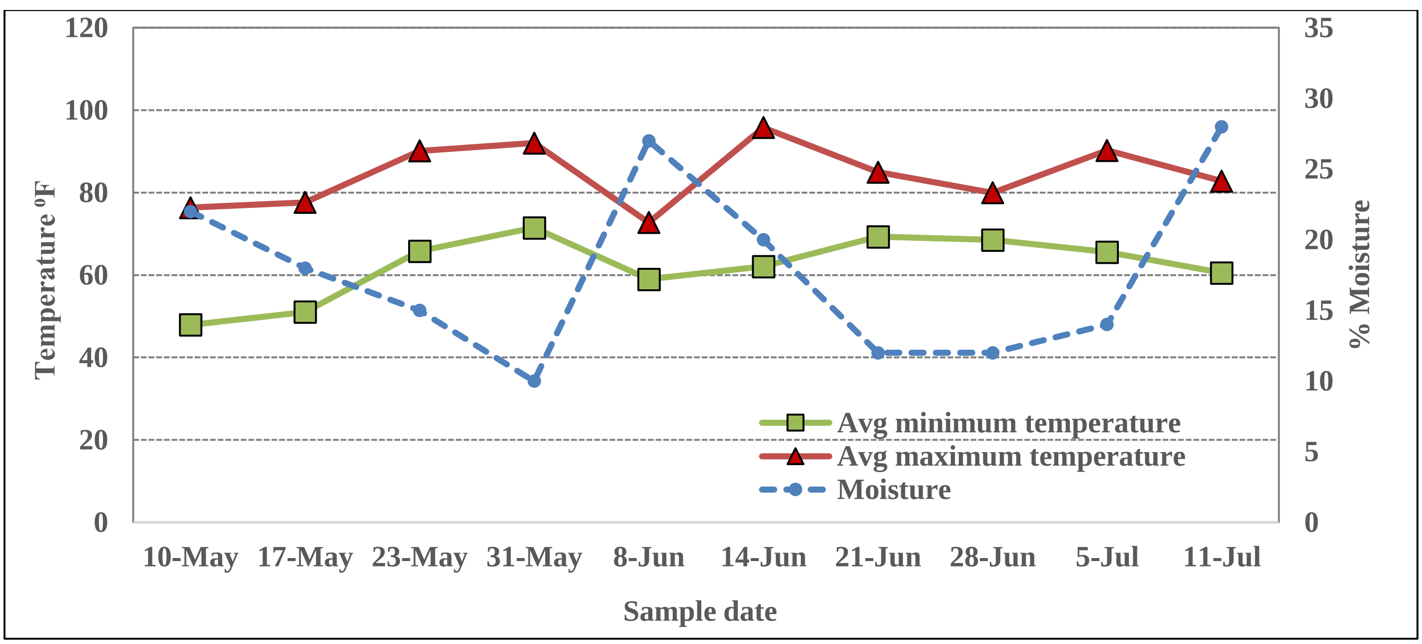

Figure 2. Average soil temperature and moisture levels in the cabbage fertility trial, Alburgh, VT, 2016.

Sweet corn fertility trial, Alburgh, VT, 2016

There were no statistical differences between treatments for number of harvested ears, plant population, yield, or stalk nitrate levels for the sweet corn (Table 12). This is likely due to the fact that the organic N from the previous year's sod became plant available for the sweet corn. It is worth noting that the sweet corn was planted almost three weeks after the cabbage, which likely impacted how much N from the sod was available to each crop.

Corn stalk nitrate levels were in the optimum range (750-2000 ppm) for all treatments, except the 'S – BM low, T – SN high' treatment, which was slightly excessive. This shows that all plots received adequate N for production.

Table 12. Sweet corn harvest yield data, Alburgh, VT, 2016.

Treatment	Harvested ears	Plant population	Yield	Stalk nitrate
	ac^{-1}	ac^{-1}	tons ac^{-1}	ppm
S – BM high	17900	11800	6.29	1310
S – BM med and SN low	20300	11500	7.48	1900
S – BM low and SN high	17900	12200	5.59	1390
T – BM high	16100	12700	5.76	1480
S – BM med, T – SN low	18700	11300	6.19	1110
S – BM low, T – SN high	16600	10200	6.20	2090
CONTROL	21100	12500	6.59	976
p-value	0.38	0.57	0.72	0.17
LSD (0.10)	NS	NS	NS	NS
Trial mean	18400	11800	6.30	1460

NS – There was no statistical difference between treatments in a particular column (p=0.10).
S = starter, applied on 9-Jun; T = topdress, applied on 23-Jun.
BM = blood meal; SN= sodium nitrate.

There were no statistical differences between treatments for plant height, ear height, moisture, ear uniformity, plot uniformity, or disease for the sweet corn (Table 13). Again this was likely due to the fact that the sod from the previous year had decomposed, become plant available, and therefore provided enough N to meet crop needs during critical N uptake.

Table 13. Sweet corn harvest quality data, continued, Alburgh, VT, 2016.

Treatment	Plant height	Ear height	Moisture	Ear uniformity	Plot uniformity	Disease
	inches	inches	%	1= low, 9= high	1= low, 9= high	0=less severe, 5=more severe
S – BM high	69.2	18.3	16.9	6.75	5.00	1.00
S – BM med and SN low	71.3	20.0	17.0	8.50	6.25	1.00
S – BM low and SN high	70.3	19.6	17.6	6.75	6.00	1.50
T – BM high	67.7	18.1	17.4	8.25	5.00	1.00
S – BM med, T – SN low	66.8	18.8	17.0	7.0	5.00	1.50

S – BM low, T – SN high	71.2	19.6	17.1	7.50	5.25	1.00
CONTROL	69.9	19.7	18.3	7.75	4.75	1.00
p-value	0.37	0.69	0.66	0.25	0.89	0.87
LSD (0.10)	NS	NS	NS	NS	NS	NS
Trial mean	69.5	19.1	17.3	7.5	5.32	1.14

NS – There was no statistical difference between treatments in a particular column (p=0.10).
S = starter, applied on 9-Jun
T = topdress, applied on 23-Jun

There also were no statistical differences observed between treatments for husked ear weight, unhusked ear weight, ear length, ear diameter, and unfilled tip (Table 14).

Table 14. Sweet corn harvest quality data, Alburgh, VT, 2016.

Treatment	Husked weight per ear	Unhusked weight per ear	Ear length	Ear diameter	Unfilled tip
	lbs	lbs	cm	cm	cm
S – BM high	0.5.24	0.718	18.3	4.33	1.38
S – BM med and SN low	0.542	0.736	18.4	4.38	1.61
S – BM low and SN high	0.457	0.616	17.4	4.24	1.85
T – BM high	0.511	0.700	18.2	4.35	1.81
S – BM med, T – SN low	0.497	0.652	18.1	4.28	1.67
S – BM low, T – SN high	0.518	0.722	18.3	4.28	1.60
CONTROL	0.543	0.725	18.5	4.43	1.87
p-value	0.75	0.53	0.43	0.96	0.48
LSD (0.10)	NS	NS	NS	NS	NS
Trial mean	0.513	0.696	18.2	4.33	1.68

NS – There was no statistical difference between treatments in a particular column (p=0.10).
S = starter, applied on 9-Jun; T = topdress, applied on 23-Jun.
BM = blood meal; SN= sodium nitrate.

Soil nitrate levels were comparable among all 7 treatments and no statistical difference was observed (Figure 3). Five out of six fertilizer treatments peaked with soil nitrate-N levels on 5-Jul, which was about one month after the starter fertilizer was applied. It is possible that this spike in nitrate level was due to more of the BM becoming plant available.

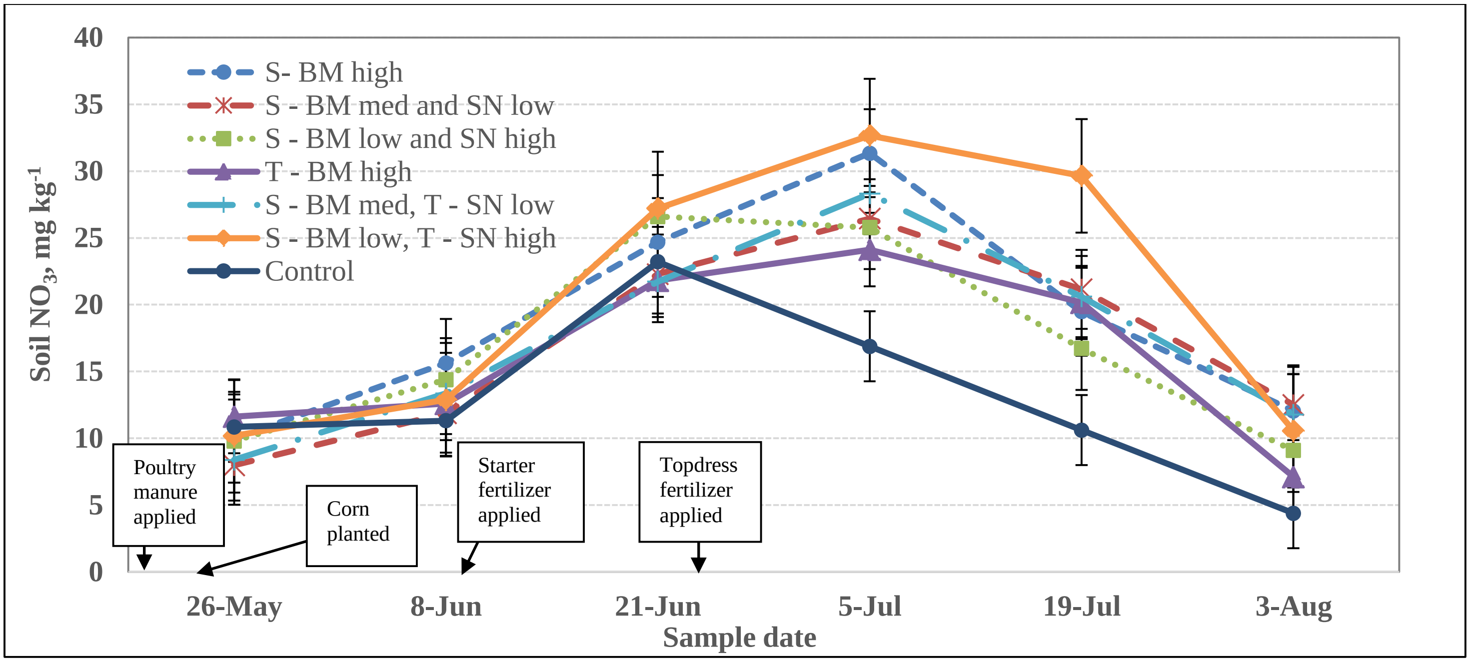

Figure 3. Soil nitrate levels in the sweet corn fertility trial, p-value > 0.24 for all sample dates, Alburgh, VT, 2016.

When the sweet corn was planted, the soil temperature was near 60°F indicating the soil microbial activity was beginning to decompose the organic matter at a faster pace (Figure 4). Soil moisture was low for portions of the season, however it increased during the month of July.

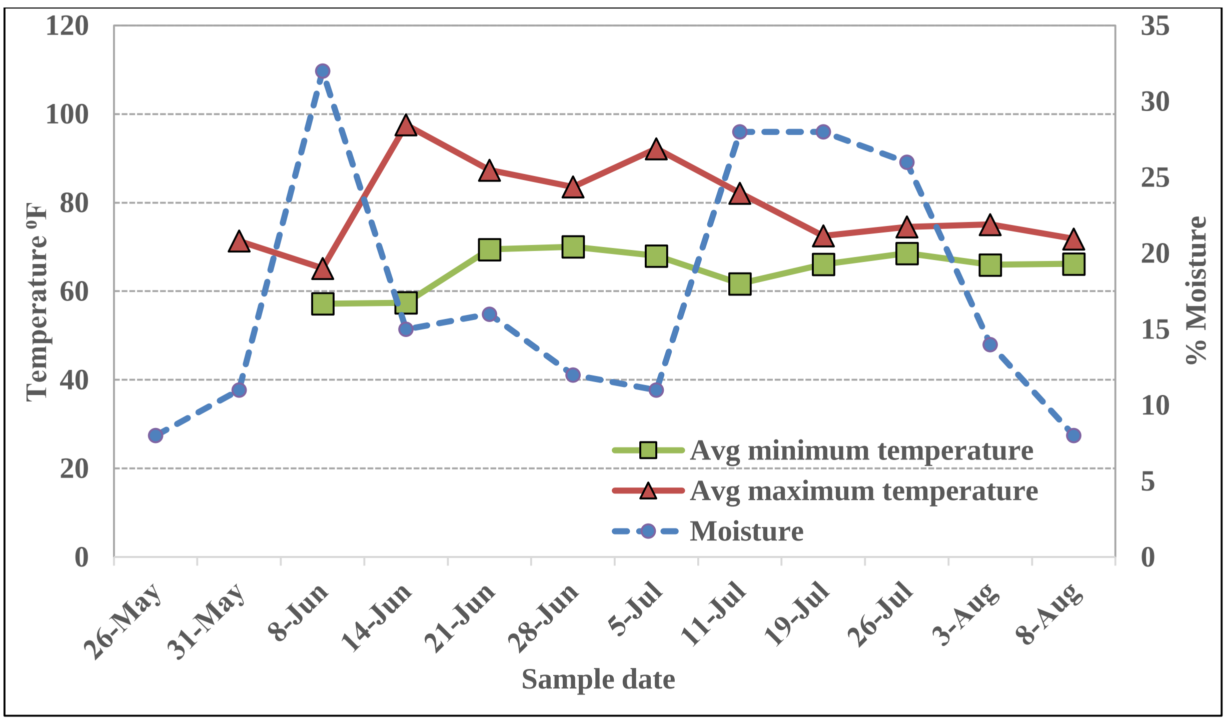

Figure 4. Average soil temperature and moisture levels in the sweet corn fertility trial, Alburgh, VT, 2016.

DISCUSSION

Addition of supplemental fertilizer that included both BM and SN improved cabbage yields above just adding BM or a plowed-down sod crop. This was likely a result of the cabbage being planted into soils with temperatures below 60°F. Low soil temperature slows/delays the release of organic N because the microbial population is not very active at that time. In addition, low soil moisture may have also reduced microbial activity and subsequent N mineralization (Figure 5). Hence the addition of SN, which is immediately 100% plant available, provided the cabbage with the N required for optimum growth. Although the BM has high concentrations of N it is in the organic form and must also be mineralized by the microbial population. In this study it took approximately 45 days for the BM to be broken down and released in plant available form. This was too late to supply the cabbage with the majority of its N needs.

The sweet corn was planted later in the season, after the soil had already warmed up to an average of 71°F and continued to experience relatively warm soil throughout its growing period (Figure 5). In comparison, the cabbage was planted into soil with an average temperature of 62°F and, although the soil warmed, it was cooler for the beginning of its growing period. In warmer soil, the sod from the previous year decomposes faster and in that process provides plant available N. In the case of sweet corn, it is likely that the plow-down sod had already substantially decomposed and began providing enough N so that supplemental fertilizer treatments did not have a significant impact on yields and quality. In addition, the sweet corn plots experienced relatively more soil moisture over the course of its entire growing period, which would also aid in sod decomposition (Figure 6).

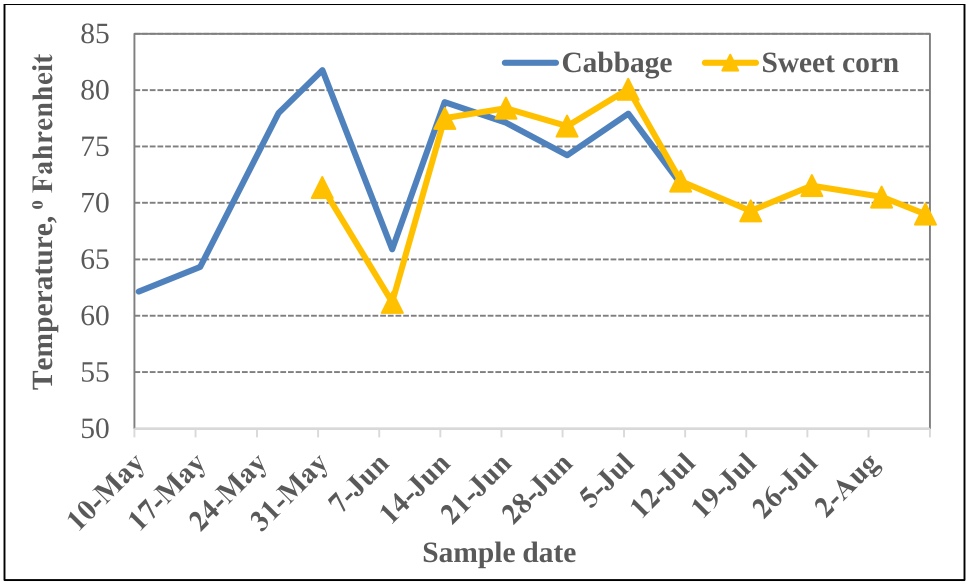

Figure 5. Average soil temperature in sweet corn and cabbage plots, Alburgh, VT, 2016.

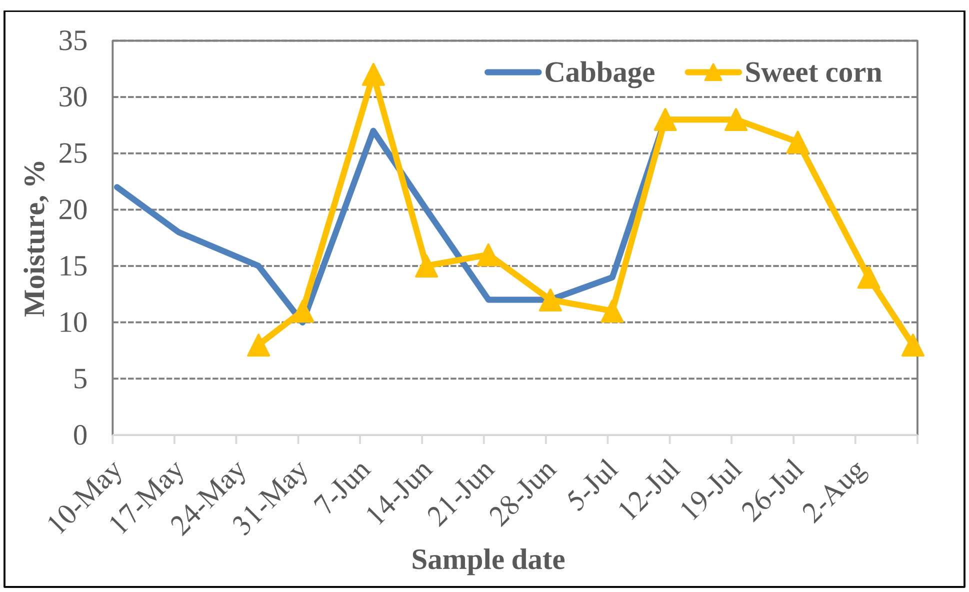

Figure 6. Average soil moisture levels in sweet corn and cabbage plots, Alburgh, VT, 2016.

The cost of the fertility treatments used in this experiment was above what most farmers typically spend, however, one must consider the return from increased yields when choosing to invest in fertility. The yield gains from an early, cool-season crop like cabbage may be worth the investment (less land needing to be cultivated, reduction in labor, monetary gain from increased yield). Farmers in the past have primarily relied on poultry manure to supply readily available N to their crops. The cost of pelletized, packaged poultry manure is $430 per ton or $5 per pound of nitrogen, while un-pelletized poultry manure is much cheaper (Lawes Ag, Brandon, VT). The cost of BM is $2428 per ton or $10.11 per pound of nitrogen (Boucher Fertilizer, Highgate Center, VT). The cost of sodium nitrate is $1060 per ton or $3.31 per pound of nitrogen (Boucher Fertilizer, Highgate Center, VT), although organic certification only permits that up to 20% of total N needs can be met using SN. However, the over application P is of major environmental concern and balancing nutrients is becoming extremely important on all farms.

Growers also will need to consider rotations involving sod crops and/or using leguminous (nitrogen-fixing) cover crops in order to meet the nitrogen needs of a crop, since they may need to limit their use of organic fertilizers containing phosphorus (based off of soil phosphorus levels, proximity to water, slope).

The goal of this project was to begin to evaluate N fertility options that would allow for minimizing poultry manure application to acceptable environmental levels. Further work needs to be conducted to develop cost effective solutions that include green manures and purchased fertilizers options.

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